Shallow-Water Reverberation

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LONG-TERM GOALS

The long-term goals of this work are: to develop a theoretical model for predicting the reverberation in shallow water, to derive both small-angle seabed reflectivity and scattering strength from reverberation data at low frequency, and to understand the physical mechanism of sea bottom scattering.

SCIENTIFIC OBJECTIVES

The scientific objective of this research is to investigate the effects of the sea bottom on sound propagation, reverberation and signal coherence in shallow water for a frequency range of 100 Hz-3000 Hz. Our specific objectives are (I) to simultaneously measure acoustic data and geologic and geophysical data at carefully chosen sea areas. (II) to derive sound velocity and attenuation in sediments from sound propagation. And (III) to characterize the seabottom scattering function from reverberation measurements.

BACKGROUND

Ocean acoustic reverberation is controlled by three major factors. The first is the forward propagation from the source to seabed scattering area; the second is the scattering process and third is the backward propagation to receivers. The seabed boundary condition and the water column dominate the 1st and 3rd factors. The seabottom scattering dominates the 2nd factor. Unfortunately, the bottom/sub-bottom geoacoustic characteristics and water column variations in coastal zones have not been well measured. Seabottom scattering mechanisms in the low frequency range are poorly understood. Thus, shallow-water reverberation relates to all of these research topics. Several theoretical models for seabed scattering have been developed. These models need to be evaluated and tested by both long-range reverberation data and low-frequency bottom scattering data. It is, therefore, desirable to derive seabottom scattering functions from at-sea reverberation data, and then to develop an easily applied reverberation model for predicting the echo-reverberation ratio in shallow water.

APPROACH

The R-mode theory is used to calculate the average reverberation level (RL) and the reverberation vertical/horizontal coherence. The sound speed and attenuation in sediments, derived from sound propagation in the same area, are used as inputs to a reverberation model. The Yellow Sea 96

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reverberation data, obtained from explosive sources and a 32 element vertical array, are used to derive seabottom scattering strength as a function of frequency and angle.

RESULTS

Fig. 1 is an example of a 1/3 Octave reverberation time series at 800 Hz, obtained in the Yellow Sea in 1996. Two semi-empirical seabottom scattering laws are used as inputs to the normal-mode reverberation model: (a) Lommel-Seeliger law (from a Russian review paper): $BS1 = \mu_1 \sin\theta$
(b) Lambert law (widely used in the USA): $BS2 = \mu_2 \sin^2\theta$. Fig. 2 and Fig. 3 show a comparison between numerical reverberation intensity and the Yellow Sea '96 data. The solid lines are obtained from the Lommel-Seeliger law. Dashed lines are obtained from the Lambert law. The Comparison shows that although the Lambert law works reasonably well at short- and mid-range, the Lommel-Seeliger law matches reverberation data much better than the Lambert law over the whole range. This result, i.e., the seabottom scattering strength decreases as grazing angle to power of 1, implies that the seabottom scattering at the Yellow Sea 96' site with very flat seabed was caused mainly by inhomogeneities in the sentiments. For frequencies that are higher than 700 Hz, the long-range reverberation data (>15s) decay slower than predictions by two models. This might be due to a water column scattering contribution, for example, fine structures, turbulence and bio-scatters in the thermocline. Reverberation-derived seabottom scattering strengths from both models increase with frequency. Fig. 4 shows the Lommel-Seeliger scattering coefficient μ_1 as a function of frequency. μ_2 has a similar dependence. Research results show that in order to derive seabottom scattering at small grazing angles from long-range reverberation, it is critical to have high quality data with high reverberation to noise ratio, and to have a ground truth measurements of sound speed/attenuation in sediments at a given experimental site.

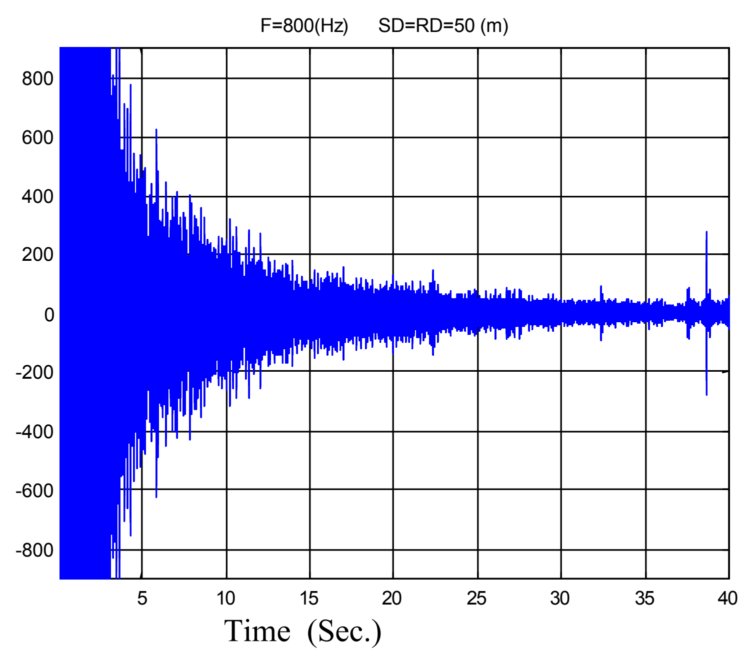

Fig. 1. 1/3 Octave reverberation time series at 800 Hz from the Yellow Sea '96 experiment.

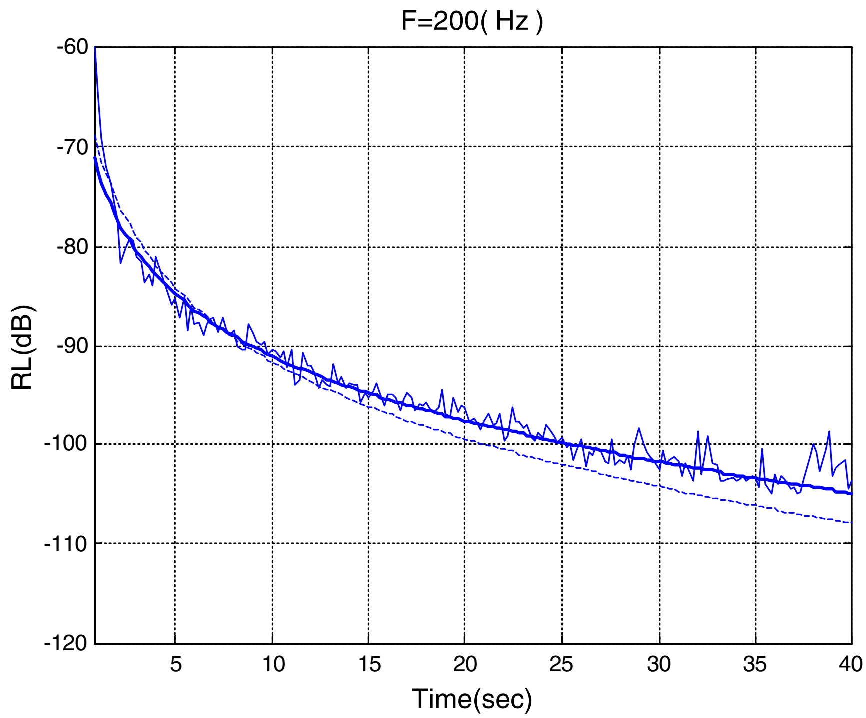

Fig. 2 Numerical simulations vs. the Yellow Sea '96 data. F = 200 Hz
Solid line for the Lommer-Seeliger law, dashed line for the Lambert law

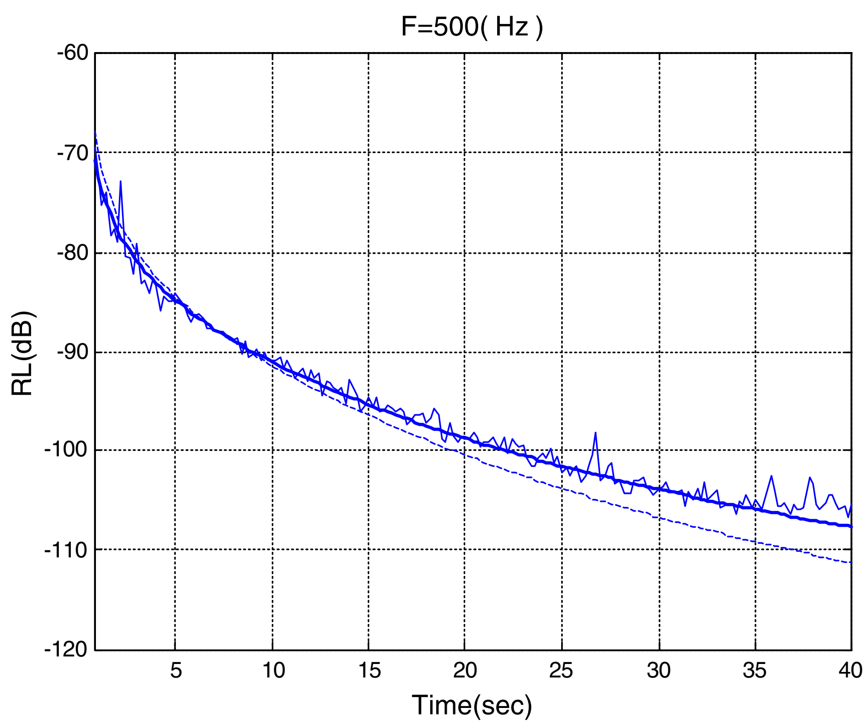

Fig. 3 Numerical simulations vs. the Yellow Sea '96 data. f = 500 Hz
Solid line for the Lommer-Seeliger law, dashed line for the Lambert law

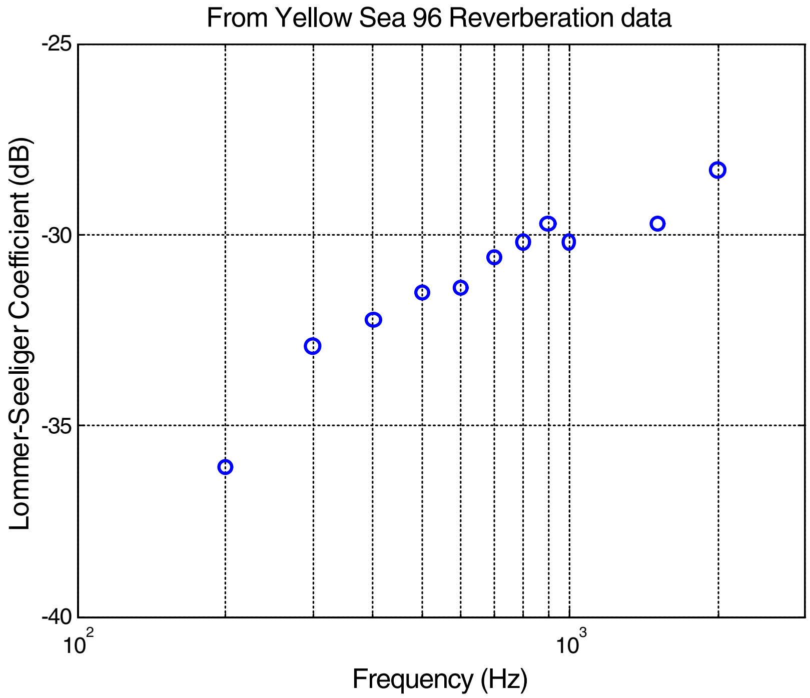

Fig. 4 Frequency dependence of the Lommer-Seelinger Scattering Coefficient $\mathbf{m}_l$